

FACULTÉ DE MÉDECINE DE PARIS

ANNÉE 1933

THÈSE

No.

POUR

LE DOCTORAT EN MÉDECINE

(Diplôme d'Etat)

PAR

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Né à Béziers (Hérault) le 9 Juillet 1906

LA CONDUCTION OSSEUSE

ET SON UTILISATION

DANS LA PROTHÈSE AUDITIVE

Président: M. F. LEMAITRE, Professeur

PARIS

AMÉDÉE LEGRAND, ÉDITEUR

93, BOULEVARD SAINT-GERMAIN, 93

1933

COMPLIMENTS OF THE
SONOTONE CORPORATION

19 West 44th Street

New York, N. Y.

Translation and Reprint of Original French Publication

FACULTY OF MEDICINE OF PARIS

THESIS

FOR

THE DEGREE OF DOCTOR OF MEDICINE

BY

Charles, Jean, Alphonse, Paul FABRE

BONE CONDUCTION

AND ITS UTILIZATION

AS AN AUDITIVE AID

President: M. F. LEMAITRE, Professor

Translated from the Original French Edition by

A. NESGE

NEW YORK

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INTRODUCTION

The present electro-acoustic arsenal for the deaf offers indeed a most varied and perfected selection of appliances. But, if their appearance differs according to makers, their principle remains generally the same; these appliances make use of the micro-telephone system and transmit the sound waves to the inner ear through the normal channel of the auditory passage. It seems, therefore, that the transmission channel through the cranium structure has not been widely used in modern electro-acoustic prothesis.

At the Tenon Hospital, we have had occasion to examine, in the Otorhino-laryngology Department of Dr. Hautant, an appliance of auditory-prothesis recently constructed in America, which makes use of the osseous transmission, while being at the same time transformable, if necessary, into a micro-telephonic apparatus. Our attention has been drawn to its purpose; however, we have found it especially interesting to know its value in considering it only from the point of view of osseous conduction. On the advice of our teacher, Dr. Hautant, we have deemed it useful and interesting to find out what results this apparatus would give. To this effect, we have made tests at the Tenon Hospital and have obtained a number of results.

In the study that we are submitting, we shall first outline a few considerations on osseous conduction; we shall then speak of appliances which improve hearing, based on this method of transmission, and shall describe the apparatus which we have used for our research work; furthermore, we shall make known our observations and the results we have obtained.

We beg, Dr. Hautant, with whom we have worked as externe, to accept herewith the expression of our deep gratitude for the advice he has given us and for the knowledge we have acquired under his guidance, while he has given us an opportunity to appreciate his great and important contribution to the development of this specialty.

We also remember with pleasure that we have worked as interne under Professor Lemaitre and we are glad to express herewith our deep gratitude for the enlightened teaching he has imparted to us at the Saint-Louis Hospital and for the honor he has conferred on us in accepting the chairmanship of our thesis.

REMARKS ON OSSEOUS CONDUCTION

The study of osseous conduction has given rise to numerous and varied works. The most important are those which treat of the various theories of this conduction; these also bring forth the most discussed problems. While, it has been admitted for some time, that the cranium bones transmit to the inner ear the vibrations of a sonorous object placed in contact with them, opinions differ as to the track these vibrations follow. Several tracks have been considered by the authors.

Does the sound reach the labyrinth directly through the otitic capsule? Some physiologists and aurists have based the theory of cranial channel proper on this hypothesis. This had already been the opinion of Haller who, in 1757, having established a distinction between aerial conduction and osseous conduction, stated that the latter passed through the skull. Erhard (1859) speaks of osseous conduction in his "Rationelle Otiatrik." According to him the apparatus of transmission, plays a part in aerial conduction only; the vibrations emitted by the cranium reach the labyrinth solely through the intermediary of the bones of the head. The cranial channel proper is according to Zimmermann also the only channel followed by the vibrations. Zimmermann has even evolved, in 1900, a theory of audition, in which he states that this is the only channel by which a sound can reach the labyrinth. Wittmaack, who in 1907, tried to locate in the ears of animals, lesions caused by intense noises, seems also to admit that the cranial channel proper only comes into play in osseous transmission.

Other authors have called attention to the fact that the tympanic membrane and the ossicle chain did not remain inert in audition by solidian canal, but they participate to the transmission by transmitting to the labyrinth the vibratory movement coming from the skull. They admit therefore, simultaneously, the cranial channel proper and the cranio-tympanic channel. This theory seems to hold the greatest number of votes. Polansky was the first to attribute to the transmission apparatus a part in osseous conduction. J. Muller, E. H. Weber, accept likewise these two channels. The first truly scientific works on this subject, are dated 1860-1870. Lucae and Politzer have the merit to have based their theories on experimental and scientific researches. According to Lucae, the vibrations reach the labyrinth through the ossicle chain and cranial channel proper, as well. Politzer points out that,

besides these two mediums, one should take into account, the vibrations transmitted from the walls of the ear-drum to the ossicles, because of the connection of the latter with the walls; other vibrations pass directly from the cranium bones onto the stirrup plate, on to the round window membrane, on through the air of the drum and that of the external auditory passage. Of all these vibrations, the only ones coming into consideration as regards auditory perception, are those which have an identical import to that of the vibrations emitted by the tympan and the ossicles. Gellé recalls in his thesis (1895) that the sound of the "vertex-diapason" reaches the labyrinth through the stirrup plate, conveyed by the temporal, whereas aerial sounds cross the whole conduction apparatus to reach the stirrup. Bonnier, Brunings, admit with Politzer that, in solidian audition, the tympanic membrane and the ossicle chain contribute to the transmission.

A new conception of osseous conduction appears with Bezold (1904) who considers only the cranio-tympanic channel. His researches have led him to eliminate the cranial channel proper. He thinks that the only sound waves perceived are those which touch the conducting apparatus. It means that for him any audition is connected with a osteo-tympanic, or better, osteo-stapedial conduction. It seems that all sound waves that cross the cranium or the labyrinth are not used in auditory perception. The part of the transmission apparatus is to transform into transversal waves, the aerial longitudinal sound waves, as well as the longitudinal waves that cross the cranium.

The waves thus modified in their orientation and directed transversally are, in short, the only ones that can be perceived by the nervous system of the ear terminal. Herzog had adopted the ideas of Bezold until 1926, at which date he was compelled to reject them after some tests made with a special apparatus. He showed experimentally that, contrary to the opinion of Bezold, the cranial channel proper enters importantly in transmission through osseous conduction. Herzog had a forerunner in Rejto, who had already in 1924, brought out a theory of osseous conduction which he upheld again at the International Congress of O. R. L. in 1928. Following some tests, in which he used an ivory model of the labyrinth, Rejto comes to the conclusion that the osseous vibrations of the cranium are transmitted to the labyrinth through both windows. Some go towards the round window, similar to those which generate from the vibration of the stirrup in the oval window in case of aerial audition; the others go towards the oval

window. The waves controlled by the oval window are in contrary direction to the movement of the stirrup. The elasticity of the two windows being different, the vibrations towards the round window are stronger; it follows that the resultant of the two kinds of vibrations is directed towards the round window, as it happens in aerial audition and the sound is perceived as in the case of this latter mode of audition.

The theories of Bezold, Politzer and other authors who admit with them the cranio-tympanic channel, alone, or associated with the cranial channel, are based upon the old conception of Helmholtz, according to which sounds penetrate into the labyrinth through the oval window. But some aurists, among whom we cite: Bechmann, Kleinschmidt, Secchi, Bingham, Bonain, believe that the conduction apparatus of the average ear, serves only for accommodation and protection; they believe, further, that the round window is the normal transmission channel of sounds to the cochlea. In fact, Lucae was one of the first to admit the supplementary function of the round window. Should this window not be attributed a part in solidian audition? In the latter case, one could add to the cranial and cranio-tympanic channels, the cranio-pneumatic channel, which would make use of the air in the drum, the promontory and the round window.

The examination of the various theories recapitulated above shows that uncertainty is still present in the mind of authors regarding the method of sound transmission to the labyrinth. If no satisfactory conception, accepted by all, exists in this respect, on the other hand the studies on osseous conduction, made from the physical and physiological angle, have given results far less disputed. From these studies we may separate the following essential facts.

A transfer of the sound by osseous channel is being effected from one ear to the other. A test made by Frey shows it: a diapason is affixed in the left pyramid of a macerated cranium; several symmetrical points of the cranium and a point of the median line are placed in contact with a microphone while the diapason vibrates; the microphone corresponds with a telephone; one discovers then that a sound coming either from the pyramid, or from the occiput puts in stronger vibration the point diametrically opposed. Another simple test can show the existence and the value of sound transmission through the skull (Lermoyez-Hautant, *Ann. mal. or.*, 1910). The right ear of A is connected by an otoscopic tube to the left ear of B, a diapason is placed on the left mastoid apophysis of A. One discovers then that B

perceives the sound of the diapason approximately as long as A and this, notwithstanding the contact point of the diapason on the left mastoid apophysis, or on the right mastoid apophysis.

All parts of the cranium do not vibrate with the same intensity. On placing a diapason on a given part of the cranium, there are two points where vibration is strongest. These two points, which are diametrically opposed, are named HARADA-MISUGI: primary point of maximum vibration and secondary point of maximum vibration; they correspond mostly. On the way that separates them there is a point of minimum vibration. Numerous are the tracks which connect a primary with a secondary and therefore there are many points of minimum vibration. A closed curve is obtained when the latter are connected. The lines of sound direction converge towards the point of maximum vibration and branch off towards the point of minimum vibration, dividing thus perpendicularly the curve of minimum vibration.

The various parts of the bones do not possess the same power of sound conduction. The cortical substance carries better than the spongy substance, the sclerotic bone better than the spongy bone; osseous conduction increases according to the firmness of the bone (Ivanof). Furthermore, this author has discovered that the conduction capacity of the cerebral matter is very poor, whereas that of the dura-mater is very good.

It is recognized that the phenomena of osseous rarefaction contribute to limit among old people the power of osseous conduction. According to Patenostre, these phenomena especially noticeable on the mastoid level, explain why in his tests 5/6 old people could not hear the watch placed on the bone.

These partial modifications in the constitution of the skull bones, which occur generally in the fifties, show a certain independence between the two labyrinths and the osseous perception on each mastoid remains rather isolated.

One can practically overlook in cochlear examinations of persons of that age, crossed audition, which is one of the principal causes of difficulty in acoumetry among adults.

The pathological modifications of bones have a certain influence on the osseous sound transmission. Passive hyperhemia, oedema, congestion, modify cranial resonance. In his experiments, Demetriades shows that paralysis of the vasomotors followed by dilatation of the vessels, increases cranial resonance on the paralyzed side; on the other hand,

the excitation of the sympathetic vibration causes its diminution. The state of the vasomotors and the cranial vessels plays, therefore, a part in osseous conduction. On the other hand, some authors have pointed out the part played by some disease. Thus, disease of the skull and its contents, disease of the nervous system (nervous disorder, psychosis), have a distinct influence on osseous transmission. Wanner, Gellé state that in this case the figures of audition are below normal. In three cases of epilepsy and in one of tetanus, Beck reaches similar conclusions, his patients not being affected with any auricular affection. The explanation in the case of Beck resides in an increase of the endocranial, or spinal pression.

The fact that the bones of the cranium conduct the sound to the inner ear has induced the authors to apply this property to otological diagnostics. Their researches date far back. The first, Caprivacious, in 1509, recommends cranial conduction in view of the diagnostic of auditory nerve-affections. According to him, if the sounds were perceived through the osseous channel, one could believe in the soundness of these nerves. E. H. Weber, guided by the experimental tests of Tortual and Wheatstone, perfected, by means of the diapason, an experiment which still bears his name and of which the value is well-known. (1829) Emerson was the first to discover that osseous conduction may be extended in affections of the transmission apparatus. A few years later, Schwabach made minute researches as to the duration of perception by osseous conduction in various affections. The determination of the time of perception is called Schwabach test. The Gellé and Bing tests give us further information on the condition of the transmission apparatus. The idea to establish a differential diagnostic between the affections of the perception apparatus and those of the transmission apparatus, is attributed to Polansky, who in 1842 makes use of a watch to this effect. In 1855, Rinne replaces the watch by a diapason and describes the test which bears his name. In this test, the osseous conduction is estimated by means of the handle, the aerial conduction by means of the fingers. His experiment was neglected until 1880, at which time Lucas points it out again and claims its true value as regards differential diagnostic between labyrinthic affections and those of the transmission apparatus. Bonnier (1901) in his test, claims the phenomenon of remote paracusis to be of real value in connection with the precocious diagnostic of progressive deafness.

The prolongation of solidian audition noticed in affections of the

middle ear, has, up to now, been explained by authors in various ways. Theories have been brought out on this subject. There is no room here for their consideration and we shall merely name the works of Mach (theory of the outlet of sound), of Lucas (theory of resonance), of Brunings (hypothesis of interference). Recent researches compel us to modify completely the ideas on increase of osseous conduction which seemed a clear fact. According to the experiments of Hallpike (1929) who was guided by a theory (screening effect) made already known in America by Knudsen and Jones (1926), osseous conduction in a person showing an impairment of the middle ear, is superior to that of a healthy person only in appearance. Hallpike supports the following ideas: if, in an ordinary room, one studies osseous audition for a certain diapason, one should consider that the ear is subject to two sound excitations, one coming from the diapason, the other from the multitude of parasite noises from which it is impossible to free oneself. In the case of a person affected by conduction deafness, one sees that the second element (aerial parasite noises) does not interfere, inasmuch as the person is deaf; the diapason should be perceived infinitely better by a normal person. Both persons being placed in similar surroundings, by means, for instance, of acoumetry in sound-proof rooms which eliminate all outside noises, osseous conduction has an equal value for both. This original conception has complicated even more the delicate problem of acoumetry.

The discovery, which was made long ago, that sound is transmitted through the bones of the cranium, has been the starting point for research work undertaken to improve audition. Various appliances have been invented which make use of osseous conduction. We shall speak of the most important ones in the following chapter.

CHAPTER II

APPLIANCES USING OSSEOUS CONDUCTION TO IMPROVE AUDITION

It was during the XVIII century that the osseous channel was used for the first time to combat deafness. Of course, far back in history, experiments in acoustics had been made in order to provide a remedy against ear deficiency, but until that time there had been no appliances based on osseous conduction of the cranial skeleton.

A German doctor named Jorissen, in 1757, was the first to advise deaf persons to place between the teeth a wooden stem specially prepared. The speaker should hold the other end of the stem between the teeth and the sound vibrations are transmitted, through this solid body, to the cranial bones and thence to the acoustic nerves. This is how the first appliance using the osseous channel was created. As we see, it is a very simple one. However, this way, the idea received its first practical use.

Ingrimas, Athanase, Kircher and Boerhaave, had already indicated, before Jorissen, this method of communicating with the deaf. After him, J. H. Winckler supported the same thesis without adding anything to it (Leipzig, 1759. *De ratione audiendi per dentes.*) From the time of the first appliance (if, however, the simple wooden stem of Jorissen deserves such name), the teeth have been selected on the skeleton as source of vibration. This is due to the fact that the teeth constitute that part of the head which transmits most clearly the sound to the inner ear. It is due to this medium that Beethoven, after becoming deaf, could in his late years hear the piano. The artist made use of a wooden stick, one extremity of which he placed in the box of the instrument while he held the other between his teeth.

In a *Mémoire* published in 1851, Bonnafont cites the case of a tuner who was afflicted with an incurable ailment of the auditory passages and the tympanic membrane, whom he advised to use, as conductor, an iron rod having at each end a plate; one plate would be placed on the piano, while the other would be applied against the head. This appliance enabled the patient to follow his profession. Ingrassias cites the case of a Spaniard who, having become deaf through the obstruction of the external auditory passage, could only hear his guitar when placing the handle of the instrument between his teeth.

The idea of Jorissen was later perfected by Itard. The principle

remains the same; transmission through the teeth is being used. However, a modification is made by the French otologist. He replaces the stem by a kind of speaking-trumpet, very thin, which has a slight opening at the end placed between the teeth of the speaker, thus transmitting the voice vibrations without interfering with articulation; the other end is slightly widened (Fig. 1).

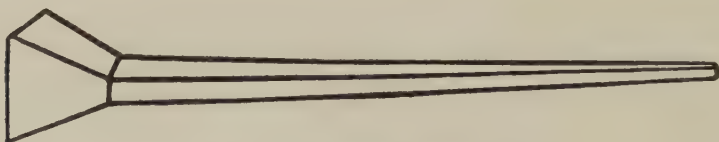


Fig. 1 — Appareil d'Itard.

While Europe outlined the first appliances, one must admit that America has been very active, afterwards, in their construction. The appliance called Dentaphone, is the work of American aurists. It is a sort of box, in which the posterior side has been replaced by a piece of pig bladder and one side removed. An iron or steel rod is placed at the center of this stretched membrane, the free extremity of the rod is widened into the shape of a little plate. The deaf person holds this little plate between his teeth; the sound waves touch the membrane and are being transmitted to the auditory nerve through the rod, the teeth and the cranial bones (Fig. 2). The Dentaphone was later on perfected by Dentaphone, American Company of Cincinnati (Ohio), which made it portable, and thus more practical, and also improved upon the clearness and the strength of the sound waves transmitted. Trials were made in the use of the American Dentaphone for the deaf and dumb, and Treibel, Head of the Royal Institute for the Deaf and Dumb in Berlin, made tests with various deaf and dumb patients. He came to unfavorable conclusions and declared the appliance to be of no value and of no assistance, at least in its actual state at that time.

The Japanese then modified the Dentaphone and tried to render it more practical. They eliminated the box and replaced it by a fan, to the lower end of which the iron rod was attached. The latter was placed in such a clever manner, that it was hardly visible when the patients held it between the teeth, the face being half hidden by the fan. While speaking against the fan, the sound waves were transmitted to the teeth and thence to the ear of the patient.

There is another appliance called Dentaphone, of which we shall say

a few words herewith, because of the similitude of names. Its principle is that of the small telephone apparatus, called "string telephone," which the children know so well. This appliance is composed of two parts: a receiver, which is a sort of acoustic wooden cornet, having at its narrow end a metallic diaphragm capable of vibrating and a transmitting contrivance formed by a wooden plate connected with the metallic membrane of the receiver through a silk thread. The deaf



Fig. 2 — Dentaphone.

person takes the plate between the teeth, points the opening of the acoustic cornet towards the listener, while stretching well the intermediary thread, which serves to transmit the vibrations.

Paladino of Naples described in 1876 an appliance, the *Fonifero*, which recalls somewhat the wooden stem of Jorissen (Fig. 3). It is a wooden stick, with a metallic semi-circle at one end which is placed on the larynx, the other end has a little disc that the patient holds between the teeth.

In 1879, Rhodes of Chicago, built his *Audiphone*. This appliance has a flexible screen of hard rubber which may be stretched like a bow by means of a few pieces of string. One stretches the screen and places its upper edge against the teeth of the upper jaw bone. The sound waves touch the rubber blade and thence are transmitted to the labyrinth (Fig. 4).

In 1880, in a report to the Academy of Sciences in Paris, Colladon de Geneva, proposes an appliance similar to that of Rhodes. The flexible screen is formed by a cardboard sheet (nettle cardboard or glazed cardboard). According to him this modification is in no way detrimen-

tal to the efficacy of the appliance, which is thus rendered accessible to all pocketbooks.

With the Audiphone begins an era of discussions. The opinions, as to its usefulness were, as we shall see, very much divided. The various results obtained with the Rhodes and Colladon appliances, created some doubts as to the interest in the use of osseous transmission. Tests were made everywhere; particularly, at the National Institute for the Deaf and Dumb in Paris, by Dr. Ladreit de Lacharriere, who did not

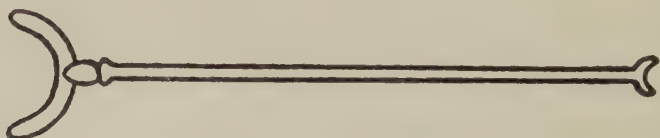


Fig. 3 — Fonifero.

verify the advantages mentioned by Rhodes and Colladon. Ladreit de Lacharriere concluded by saying: How are we to explain the experiments of M. Colladon, and mine, without thinking that the author may have been under a delusion and that lip-reading has sometimes made up for the deficiency of the instrument?" This was not the opinion of Rhodes, who has demonstrated experimentally in the United States, that many deaf and dumb persons could distinguish the musical sounds of some instruments (articulation of the voice) and that their oral education was considerably shortened with his apparatus. He had also discovered favorable results in persons afflicted by simple deafness. However, at the meeting of the Academy of Sciences in 1880, M. Dumas spoke of a "great discovery" when mentioning the Colladon apparatus. In America, Knapp of New York stated that the Audiphone of Rhodes was not without value and has recommended same to persons to whom the acoustic cornet did not bring relief, or who had a very unpleasant sensation in the ear when using it. Turnbull of Philadelphia did not think the Audiphone of appreciable usefulness. He stated that a certain soundness of the acoustic nerves, and firm incisors, well fastened in the upper jaw, were needed, to show the real value of the appliance. One could not say, he added, to what degree the instrument might prove useful in teaching deaf and dumb persons. Green was of the same opinion regarding the acoustic soundness thesis, which governs the use of the Audiphone. Last, keeping a happy medium, Hugentoble of Lyon drew the following conclusions from his experiments in 1880:

1—The Audiphone may replace the ordinary acoustic cornet in certain cases of deafness.

2—There is a steady and gradual proportion between the sensitive-ness of the acoustic nerve and the results obtained with the Audiphone.

3—The Audiphone cannot render valuable services to the real deaf and dumb people.

4—We cannot believe that the Audiphone could ever make the deaf and dumb hear a musical composition, or an intimate conversation; but we see in it, an instrument which, when perfected, will one day enable them to have an idea of isolated sounds, which may lead us to eliminate almost entirely the monotony of the speaking deaf.

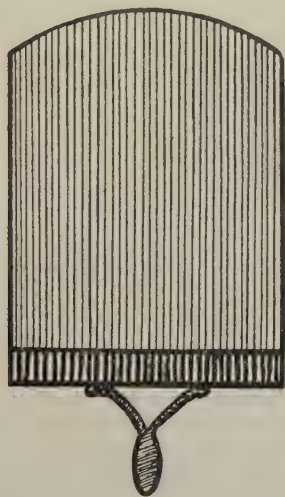


Fig. 4 — Audiphone de Rhodes.

The invention of the phonograph enabled Loewe to build an appliance which is an application of Edison's work to auricular prothesis. A cornet, having at its lower end a vibrating membrane, at the center of which a steel point is affixed, is placed at the center of the forehead. The vibrations are transmitted through the point to the bones of the cranium.

The various appliances that we have just considered have never truly been favored by the patients. While they have at one time drawn the attention of aurists, one must admit that they are of little practical use. This explains why modern authors have given these appliances a secondary place only in auditory prothesis.

Closer to our times, the discovery of electricity has been the starting

point of new developments in the evolution of the fight against deafness. Only 25 years have elapsed since one began using electricity to help deaf persons hear. One cannot overlook the services rendered them by the present microphonic appliances. But, while the number of micro-telephone systems making use of the normal aerial channel is great and varied, on the other hand, that of electro-acoustic appliances using solely osseous cranial conduction, is extremely small. It seems that up to now osseous transmission proper has not as yet derived from the use of electricity the same great benefits as aerial transmission has.

The appliances of which we shall speak presently, do not fulfill the necessary conditions to be used in the current daily life of the deaf. They are generally for radio-technical amplification, obtained with vacuum tubes. It is easy to understand the disadvantages of their dimensions, their weight, which do not make them easily transportable. They can be used more readily at concerts, the theatre, and for listening to the radio.

In this respect, I wish to mention that Dr. Ferriere of Geneva (who thought that one could easily substitute, with a great number of deaf persons, to the transmission by normal channel, a transmission by cranio-facial contact, particularly through the teeth), would use to this end a metallic rod attached on to a listening contrivance and to which can be affixed a small ivory contact, approximately one centimetre long, which is placed against the teeth. The listening apparatus is hidden in the palm of the hand, or on the knees and the patient places the little individual ivory device in contact with his upper teeth, after having affixed it to the metallic rod of the listening device.

Dr. Eichorn of Zurich has built an electrostatic telephone receiver called Radiophone which enables deaf persons to hear radiophonic sounds. This receiver, the handle of which is connected to the loud-speaker post, may be held against the ear or placed in contact with other parts of the head, the cheeks, the temples, the forehead, the top of the cranium, thus using osseous transmission.

H. Gernsback, American technician and journalist, has more recently built an appliance, called Osophone, for radio-technical amplification. It consists of an electro-magnetic system with vibrating armature connected with an amplifcator having wireless bulbs. The deaf person presses against her teeth the end of the vibrating armature and hears the sounds.

At the German Society of O. R. L. Congress, held in Basle in 1930,

Schwarz mentions the work undertaken in Germany to build "osseous conduction telephones." The principle is from Griesmann and Pohlmann and consists in affixing on the vibrating membranes of telephone receivers, some little tacks which are placed in contact with the cranial bones.

Barany did later on build an electro-dynamic appliance based on the same principle and giving better results. But according to the advice of Schwarz, and also Kahler, while these osseous conduction telephones have a certain value as regards diagnosis, they do not as yet fulfill the necessary conditions required for a real auditory prosthesis appliance. It would be necessary to invent a small device, much reduced, light enough to be easily transportable and almost invisible when being used. Furthermore, the pressure of an organ on the cranial bones, on the mastoid apophysis, should not bring forth a local inflammation.

These conditions seem to have been complied with in an appliance recently built in America, according to the data furnished by Dr. Lieber of New York. The sound waves which are caught by a microphone are amplified by means of a special device and reach a small vibrating organ which may be placed on the cranial bones and thus transmit its vibrations to the skull.

This appliance is composed of the following parts:

- 1—A transmitter
- 2—A vibrator
- 3—An amplifier
- 4—A battery
- 5—Wires which connect the various parts (Fig. 5).

The Transmitter—It is a transmitter with two microphones which has a sensitiveness and an unusual purity of sound, due to its shape, which has been carefully chosen, and to its resonance chamber, which is well rounded in front of the diaphragms. There is on top a piece of bakelite, marked "T" at both ends and by means of which the wires are branched off—(we shall mention this piece of bakelite again when speaking about the wires). At the base of the transmitter is the device comprising the interrupter combined with the volume control (Fig. 5). The microphone may thus be regulated by means of a small button, which enables to pass gradually from a minimum to a maximum intensity. At the base of the transmitter is a revolving nickel foot. When this foot is turned at right angle to the transmitter, the latter is in vertical position when placed on a table. The transmitter has, at the back, a

hook with spring, by which it can be fastened to the clothing. In order to function, the transmitter must always be in a vertical position.

The Vibrator—It is a device shaped like a keystone of small dimension and very light. On one of its faces, there is a small ring slightly raised containing a gold button hardly protruding. There are two holes at one end (of different diameters) which are to receive one end of the conducting wire. This vibrator has a vibrating metallic diaphragm placed opposite the polar strain of an electro-magnet, fairly powerful in spite of its small size (Fig. 6).

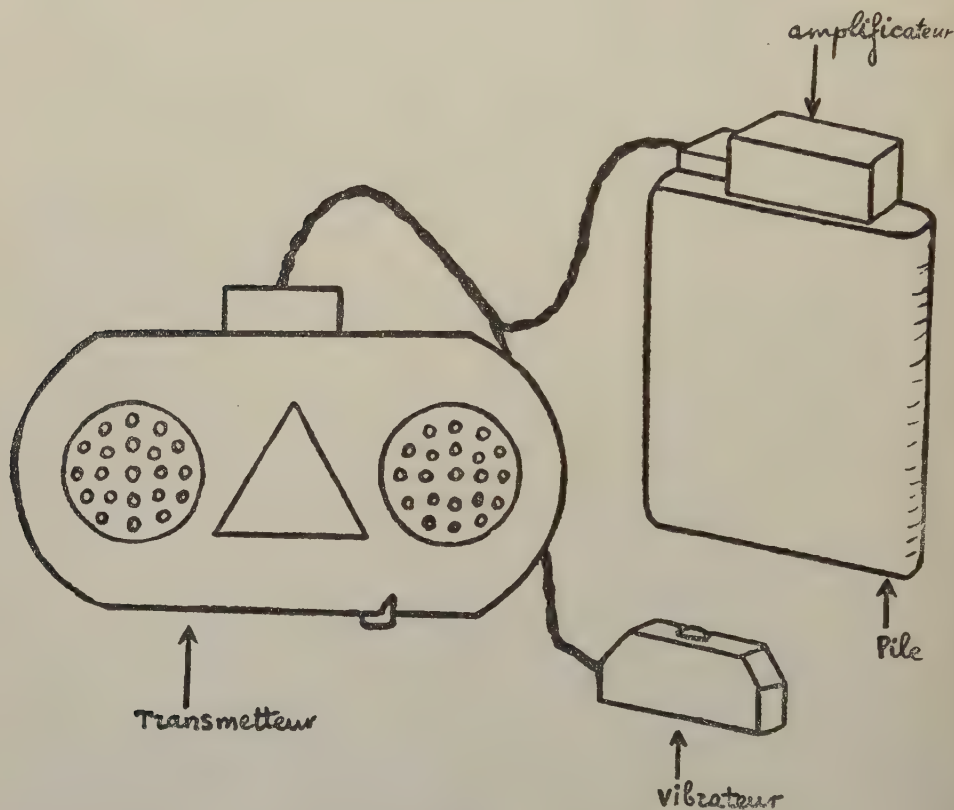


Fig. 5

At the center of the diaphragm is a metallic rod, which is ended externally by the small gold button already mentioned. The vibrator is used by holding rather firmly the button pressed flat against the bony parts of the head (mastoids, forehead, the top of the nose), or against the teeth. A little fastener, easily concealed, holds the appliance against the mastoids; the vibrator can also be attached to a tortoise-shell handle similar to that of a lorgnette.

The Amplifier—This amplifier of an entirely new type, extremely powerful and effective, is of a rectangular shape. It has three holes at one end (one large and two small) which are made to receive one end of the conducting wire, and on one of its faces two metallic pins (of different diameter) to establish contact with the current generator. It provides a microphonic relay, as indicated in Fig. 7.

A case contains two cobalt steel magnets and a spool placed around a soft iron core crossed by the microphonic current. Opposite this polar strain is a metallic diaphragm holding a small microphonic chamber containing carbon granules. The metallic diaphragm vibrates under the action of attractions and repulsions provoked by the electro-magnet and acts thus upon the small secondary microphone with carbon

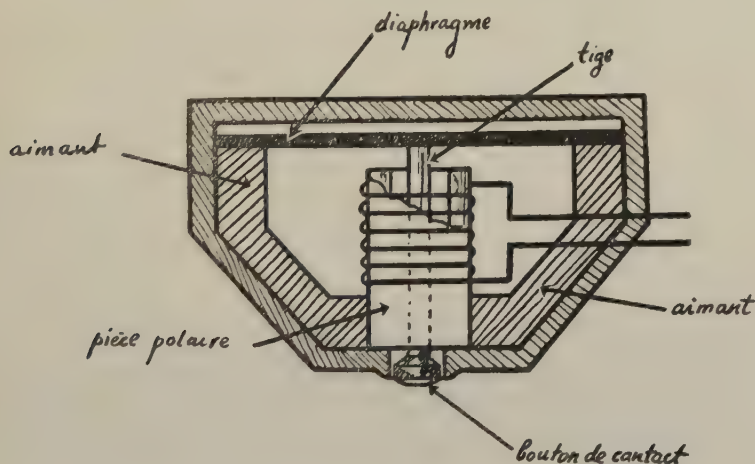


Fig. 6

granules, which in turn brings about microphonic currents in the vibrator. The amplifier fixed on the battery does not function if this generator is placed flat on one of its large faces.

The Battery—There are three types of dry batteries: one with three volts (2 elements), another with 4 volts ($\frac{1}{2}$) (3 elements), and a third with 4 volts $\frac{1}{2}$ (3 elements) of the same power as the preceding one, but more lasting. This last one should be used in preference for osseous conduction. In order to extend the duration of the batteries and obtain a better yield from them it is recommended to use several alternately. They give better service when not used for 24 hours after 4 or 6 hours continual use. At the top of the battery are two holes to receive the plugs of the amplifier.

The Conducting Wires—The wire is thin and very flexible and has three distinct extremities, one connected with the transmitter, one with the battery through the amplifier, the third with the vibrator. The contacts are made by means of bakelite pieces, a brown one marked T, having three metallic plugs (2 large, 1. small) for the transmitter, and a black one marked B, for the battery, having also three plugs (1 large, 2 small). On the third end of the wire, for the vibrator, there are two metallic plugs (1 small, 1 large), which should be firmly introduced in the corresponding holes of the vibrator. This third end may be connected with a receiver if the normal aerial canal is being used. In this case, it is preferable to remove the amplifier from the circuit.

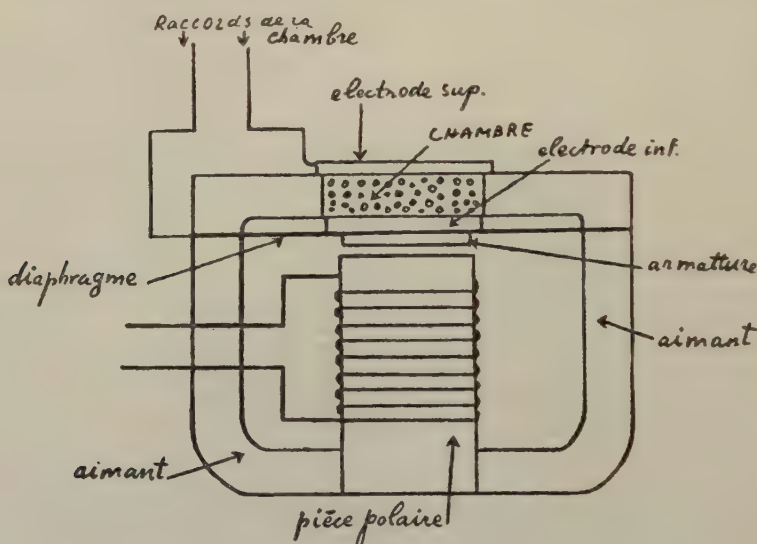


Fig. 7

When worn, the appliance may be easily hidden. The battery can be placed in a pocket, the transmitter can be attached to the vest, or any other garment, by means of its hook, or carried in the pocket. As to the vibrator, it is by means of the head fastener, carried almost hidden behind the ear.

The most recent improvements of modern electro-acoustic technique, have been used in the construction of the appliance we have just described. Furthermore, we used it in order to find out if it is actually possible to grant a value to an appliance using osseous conduction. For these two reasons, we have described it at length in the review we have made in this chapter.

CHAPTER III

OBSERVATIONS

OBSERVATION I

Miss F., age 38, nurse, shows a bilateral deafness which started at the age of 29. It was first located in the right ear, but it progressively reached the left ear. No auricular affection in her family, no running. This deafness causes buzzing which is really only felt at the menstruation periods. The patient hears better when there is noise. Insufflations have been made, but have brought no amelioration. Seeing that her deafness was increasing noticeably, the patient studied lip-reading and tried acoustic re-education. She speaks in a low voice. Otoscopic and rhinoscopic examinations detect nothing abnormal.

Acoumetric Examination

	OD	OG
Whispering voice	0	0
Loud voice	auricle	auricle
Schwabach	25"	
Weber	indifferent	
Rinne	negatif	negatif
435	0"	5"
Inferior limit	raised	
Superior limit (monocord)	12,000	13,000

Paracusis of Willis and Bonnier. Test of Gellé, negative.

Test of the Appliance—The patient says she can hear very well and can follow a conversation in low voice in front of the microphone. Loud speaking is heard up to 1 m.50 from the microphone, similar distance for both ears. The patient states that she can detect the voice clearly without any disagreeable resonance occurring.

OBSERVATION II

Mrs. M. S., age 37, working in a perfume manufacture, became progressively deaf around 24. The deafness began in the left ear and reached the right ear a few years later, with buzzing. The patient's mother, age 60, is deaf also and her father, age 65, examined in the O. R. L. Department of Tenon, is "hard of hearing." No rhino-pharyngeal past.

In 1925, a specialist consulted, spoke of dry otitis and advised massage of the tympan and insufflations which brought about no improvement.

Tympanum normal. Rhinoscopic examination shows nothing.

Acoumetric Examination

	OD	OG
Whispering voice	0	0
Loud voice	0 ^m , 20	auricle
Schwabach		17"
Weber		
Rinne	negative	negative
435	0"	0"
Inferior limit		raised
Superior limit	11,000	8,000

Test of Appliance—The vibrator applied on the right mastoid, the patient hears clearly and can very well follow a conversation carried in a loud voice three metres away from the microphone. For the left ear, the maximum distance is 2m.50. If the vibrator is placed on the upper jaw, the maxima distances are increased of about 1 metre, but the patient says that the hearing becomes then somewhat painful.

OBSERVATION III

Mrs. B. A., age 36, merchant, complains of progressive deafness dating back to five years ago, which was felt first a few months after her first confinement. This deafness, especially at the left, is attended by buzzing noises, very intense, which annoy the patient to the highest degree, and has suddenly grown worse during a second confinement, two years ago. The deafness increases at menstruation time. Mother deaf very young. Various treatments have been tried (diathermy, insufflations); no improvement.

Otoscopic examination shows nothing.

Acoumetric Examination

	OD	OG
Whispering voice	auricle	0
Loud voice	0 ^m , 20	0 ^m , 10
Schwabach		25"
Weber		indifferent
Rinne	negative	negative
435	30"	20"
Inferior limit	128	128
Superior limit	10,000	7,000

Willis Paracusis. The patient says she can hear the sound of a diapa-son ut² placed on the styloid apophysis of the cubit and the Gellé test is negative.

Test of Appliance—The whispering voice is not clearly heard. The loud voice is heard at a distance of 1 metre from the microphone, by the right ear, and at 0.m 50 by the left ear. If the vibrator is placed on the frontal bones, the audition is not much improved.

OBSERVATION IV

V. M., age 30, employed in a Parisian hospital, has been deaf since the age of 10. She had at that time a touch of rheumatism in the left knee and in the right wrist. Deafness appeared progressively, together with buzzing. Five years ago, in the O. R. L. Department of Tenon, they gave her an antispecific treatment, as well as a diathermic treatment. The ophtalmology section, where the patient has been under observation several months ago, has given us further the following information: chorio-retinite, myopic heredo-specific, interstitial keratite at right, B.-W. negative, 7 injections of cyanide.

The otoscopic examination shows retracted and thickened tympanum.

Acoumetric Examination

	OD	OG
Whispering voice	0	0 ^m , 10
Loud voice	0	1 metre
Schwabach		nul
Weber		nul
Rinne	The aerial audition of Ut, lasts a few seconds only. Solidian audition of the same diapason is negative.	
435	15"	20"
Inferior limit	128	128
Superior limit	8,000	9,000

The caloric test shows a slight nystagmic reaction in the left ear. At the right the vestibular labyrinth is not excitable. The patient shows, furthermore, a distinct Hennebert sign.

Test of Appliance—Tried in succession on the mastoids, right, left, on the frontal bones, the teeth, the top of the nose, the appliance does not help the patient who cannot hear the spoken voice.

OBSERVATION V

Mrs. M. L. J., age 44, office worker, has been deaf for about 15 years. After her third confinement she felt she could not hear as well through the right ear first, then on both sides. There has been no noticeable increase of deafness since that time.

She hears better when there is noise. Her ears did never run. She has been attended at the beginning by several aurists who diagnosed a catarrhal affection of the middle ear.

The tympanum are mobile, but somewhat thickened and of a milky color.

Acoumetric Examination

	OD	OG
Whispering voice	auricle	auricle
Loud voice	0m, 50	0m, 50
Schwabach		20"
Weber		indifferent
Rinne	negative	negative
435	30"	30"
Inferior limit		raised
Superior limit	11,000	10,000

Test of Appliance—The patient hears the whispered voice at a distance of 0 m50 of the microphone. The loud speaking voice is heard by the right ear at 2 meters, by the left ear at 1 m 50 of the microphone, the vibrator being placed in succession on each mastoid.

OBSERVATION VI

Mrs. L., age 49, laundress, complains of progressive deafness which started 10 years ago, after a surgical operation for bilateral Salpingo-ovarite. No running. She feels buzzing, but no vertigo. Her deafness does not change according to atmospheric conditions. The patient does not hear better while there is noise. A insufflation treatment has given no improvement. The right ear, according to the patient, is the best.

Tympanum somewhat white.

Acoumetric Examination

	OD	OG
Whispering voice	auricle	auricle
Loud voice	1 metre	0m, 50
Schwabach		15"
Weber		indifferent
Rinne	negative	negative
435	30"	25"
Inferior limit	128	128
Superior limit	7,000	7,000

Test of Appliance—The whispered voice is not heard distinctly and the patient does not always repeat exactly the pronounced sentences. On the other hand, the loud voice is heard at 1 m50 of the microphone by the right ear, and 1 meter by the left ear. The application of the vibrator on other parts of the cranio-facial skeleton, does not change the degree of hearing.

OBSERVATION VII

M. T., aged 70, formerly a lithographer, has been deaf since 1914, at which date a serious attack occurred with buzzing, vertigo, vomiting, and a sudden deafness, especially in the left ear. Since then, the

patient has continually had similar attacks, which, though less acute, have occurred at irregular intervals producing each time an increase of deafness. At present, the patient is troubled with continual vertigo and buzzing, and his left ear is almost totally deaf; he says that the right ear is less affected. While undergoing treatment, lumbar punctures were administered. No running. His arterial tension is 18-10 with Vaquez. The pupils react slightly under the light; tympanum normal.

Acoumetric Examination

Whispering voice	OD	OG
Loud voice	pavillon	0
Schwabach	1 metre	0m, 10
Weber	7"	
Rinne	positive (much decreased)	?
435	25"	0"
Inferior limit	raised	
Superior limit	3,000	7,000

Test of Appliance—No improvement is brought about by the appliance, the patient not being able to understand the spoken voice in front of the microphone and this, notwithstanding the application point of the vibrator on the cranio-facial skeleton.

OBSERVATION VIII

M. G. B., age 40, fitter, has a chronic "otorrhée," bilateral, since childhood. The running only annoyed him and up to lately, his audition was relatively good. Since 5 or 6 years, the audition on the left side has decreased. He has lately had vertigo: intense buzzing of the right ear and sudden decrease in hearing, which has since persisted. Otoscopic examination of the right and left sides shows some pus in one of the auditory canals, which presents exostosis impeding considerably the examination with speculum. No mastoid pains, no temperature. It is necessary to shout, in order to make the patient hear.

Acoumetric Examination

Whispering voice	OD	OG
Loud voice	0	0m, 20
Schwabach	0m, 15	2 mètres
Weber	15"	
Rinne	negative (false negative, Rinne negative)	
435	0"	20"
Inferior limit	raised	
Superior limit	6,000	8,000

He was sent to the Hospital of Tenon in order to operate on the right ear. But we gave him first a test with the appliance to see what

the result would be in this case of deafness through “labyrinthitis” of optical origin.

Test of Appliance—When the vibrator is placed on the left mastoid, the hearing distance is improved (0m,70). The raised voice is clearly heard at a distance of more than three meters from the microphone. At the right, the whispered voice is heard at a distance of 0m,20 and the loud voice at 0m,50, from the microphone.

OBSERVATION IX

Mrs. J. P., age 53, having worked as an operator in metal plating and cutting, is affected with progressive bilateral deafness which started at the age of 12. This deafness, at present very pronounced, is attended by buzzing. No running. No deafness in the family. It is necessary to shout very loud in front of the auricle in order that the patient may hear, even imperfectly. The otoscopic examination does not reveal anything in particular.

<i>Acoumetric Examination</i>		
	OD	OG
Whispering voice	0	0
Loud voice	0	0
Schwabach		10"
Weber		indifferent
Rinne	negative	negative
435	0"	0"
Inferior limit	very much raised	
Superior limit	(The lowest sounds of the monocord are not heard)	

Test of Appliance—The appliance does not bring any improvement. The patient says she can hear the sounds, but does not understand and cannot repeat the sentences pronounced in front of the microphone, wherever the appliance is placed: mastoids, frontal bones, and teeth.

OBSERVATION X

Mrs. L. Q., typist, age 46, has a bilateral deafness, especially on the left side. Her record shows that she had a medium otitis at the left when 20 years old. This purulent otitis, which lasted one month, was the cause of the hypoacusis which has been treated by insufflations. Ten years ago there was a recrudescence of running and ablation of popypus in the left drum, and approximately four years ago, after the influenza, deafness increased. No running on the right side, but progressive weakening of the auditory acuteness; buzzing in both ears. Otosopic examination shows a contracted tympanum at the left, with

scars of chronic otitis. At right, tympanum thickened, whitish, and contracted.

Acoumetric Examination		
Whispering voice	OD 0 ^m , 10	OG auricle
Loud voice	1 meter	1 meter
Schwabach		30"
Weber		
Rinne	negative	negative
435	20"	20"
Inferior limit	128	128
Superior limit	10,000	10,000

Test of Appliance—The apparatus brings improvement in the state of the patient. She can follow a conversation spoken in a loud voice at a distance of three meters from the microphone. The distance from which she can hear the whispered voice is improved and thanks to the appliance it is about 1 meter, the vibrator being placed on the left or right mastoid.

OBSERVATION XI

Miss M. Le., embroiderer, age 33, has been deaf since the age of 9, at which date she contracted a purulent otitis which lasted several months. The running recurred at the age of 20, lasting approximately three years and is the cause of a strong increase of deafness. The left ear has never run, but the increase in deafness has been treated by insufflations which have somewhat improved hearing. The patient had tympanum massage on both sides. Deafness varies according to atmospheric conditions and the patient hears better when there is noise; she even states "that she has come to like noise, which improves her hearing." She speaks in a low voice.

Otoscopic examination shows at right scars of otitis, at left an almost normal tympanum picture.

Acoumetric Examination		
Whispering voice	OD auricle	OG 0
Loud voice	0 ^m , 50	0 ^m , 40
Schwabach		20"
Weber		
Rinne	negative	negative
435	20"	0"
Inferior limit	128	128
Superior limit	13,000	10,000

Test of Appliance—The apparatus brings a great improvement in the state of the patient. The loud voice is heard at a distance of 3 meters from the microphone, the whispered voice at 0m, 50, when the

vibrator is placed on the left mastoid; if applied on the right mastoid, there is an improvement of 0m. 50 in the distance from which the raised voice is heard; no change for the whispered voice.

OBSERVATION XII

Miss L. C., dressmaker, age 63, has a marked bilateral deafness. Since the age of 7, her ears have run intermittently. This chronic bilateral "otorrhée" is attended by buzzing. At present, otoscopic examination shows an identical picture on both sides, which consists of a large perforation covering almost the whole tympanic membrane and through which may be seen an inner drum of a roseate tint. A little pus at left.

Acoumetric Examination		
	OD	OG
Whispering voice	0	0
Loud voice	auricle	auricle
Schwabach	15"	
Weber	indifferent	
Rinne	negative	negative
435	10"	10"
Inferior limit	128	128
Superior limit	(The lowest sounds of the monocord are not heard)	

Examination of the vestibular labyrinth shows caloric and rotatory normal tests.

Test of Appliance—The patient, very nervous, cannot get used to wearing the appliance and it is necessary to regulate the microphone in order to decrease its intensity. The vibrator when applied on the right mastoid, enables the patient to hear the loud voice at a distance of 2 meters, the whispered voice at a distance of 0m.50. When placed on the left mastoid, the patient can hear the loud voice at a distance of 1 meter and the whispered voice at a distance of 0m.20. The patient hears less well if the vibrator is placed on the frontal bones.

CHAPTER IV

RESULTS

We have used the electro-acoustic appliance of Dr. Lieber, in 12 cases of deafness, as per preceding observations. All the patients we examined were afflicted by bilateral deafness, some since childhood. Furthermore, medical treatment had not improved this deafness (this having been tried with several patients). The observations we made enable us to classify the 12 patients as follows:

- 3 "Otospongioses" (Observations I, III, IX.)
- 6 Sclerosis of the middle ear (Observations II, V, VI, X, XI, XII.)
- 3 Deafness of a labyrinthic type (Observations IV, VII, VIII.)

In three of these twelve cases, the appliance did not bring any improvement, in the other 9 cases there has been more or less improvement of audition. The $\frac{3}{4}$ of the case of deafness examined have been improved. The tests of the appliance may be summed up as follows:

No improvement: (Obs. IV, VII, IX.)

Medium improvement: (Obs. III, VI, VIII.)

Good improvement: (Obs. I, II, V, X, XI, XII.)

Among the cases which have not improved, we note:

I. A labyrinth deafness, heredo-specific (Obs. IV). A simple interpretation of the acoumetric formula could have foretold this result, solidian audition studied by means of 128, being negative.

II. A chronic labyrinth deafness, probably caused by bad circulation, and resulting in vertigo of Meniere (Obs. VII). Solidian audition was greatly weakened (Schwabach: 7'') and the inner left ear much affected.

III. An advanced "otospongiose" with important labyrinthic participation (cochlear form) (Obs. IX), as shown by the decreased Schwabach, the lowering of the superior limit of sounds and an aerial perception of "la'", negative.

If only a medium improvement is observed in cases III, VI and VIII, it is because in these cases, the lesions have reached the inner ear, as proved by the decrease of aerial perception of la' and the lowering of the superior limit of sounds.

In short, in cases where the improvement is particularly distinct, we find a solidian audition extended and the inner ear less affected.

It does not seem to us that there is a really distinct improvement of hearing when the vibrator is applied at points of the cranio-facial skeleton, others than the mastoids. In one case, however, (Obs. II.) there is advantage in applying the vibrator on the upper jaw.

Are there elective points on the mastoid itself? We do not think so. If a slight change of place improves the hearing, it is because the first contact was not well established. During our tests, we have sometimes changed the position of the vibrator on the mastoid, in order to obtain a better perception. We think that the variations of the quality of perception on such a limited space, are due to the fact that often the button of the vibrator is not held strongly enough when pressed flat on the osseous part. On some mastoids, in fact, the intimate contact, more or less difficult to obtain, owing to the osseous architecture, must be carefully placed and verified, which necessitates some groping.

Finally, the patients examined have declared that the perception by osseous conduction was clear, the resonance at a minimum and the feeling less unpleasant than with the "listener."

CONCLUSIONS

1. Osseous conduction has been the subject of much study, especially abroad. The various aspects offered by this chapter of otology, have been considered by the authors. But uncertainty still prevails as to the track followed by vibrations.

2. For some time this transmission medium has been used in auditory prothesis and there are acoustic appliances and electro-acoustic appliances, based on osseous conduction. The first are of little use and the latter, of limited number only, do not fulfill the requirements that a real appliance of auricular prothesis should have.

The electro-acoustic apparatus of Dr. Lieber, is a new contribution to the fight against deafness and shows an improvement deserving of interest. The various parts which compose it are of small dimensions and make this apparatus easily transportable and easy to conceal, while it is of a remarkable effectiveness.

3. The observations that we have obtained with this appliance, give us the authority to state that osseous conduction, used in this manner, may at present, be taken into consideration. It shows that audition is improved with this apparatus which, though it does not claim to cure deafness, shows nevertheless real advantages in cases where osseous audition is still preserved or, still more so where it is extended.

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